CHAPTER 5

Periphyton Habitat Suitability Index

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General Description

Periphyton (**Figure 5-1**) is a ubiquitous feature of Everglades marshes and has been shown to respond strongly in structure and function to alterations in both hydrologic conditions and water quality. Through interactions with the physiochemical environment and other biota, periphyton influences many features of the Everglades ecosystem including soil quality, secondary production, concentration of nutrients, and dissolved gasses. Therefore, it is not only a sensitive indicator of environmental change but can serve as an early warning signal of impending change in other components of the ecosystem.

Figure 5-1. Floating periphyton mats.

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Studies of variation in Everglades periphyton along naturally existing and experimentally created gradients have found strong relationships of species composition, nutrient content and ratios, structure (growth form), calcite content, and physiology (i.e., nutrient uptake, productivity) to water quality and quantity (Browder et al. 1982, Swift and Nicholas 1987, Grimshaw et al. 1993, Raschke 1993, Vymazal and Richardson 1995, McCormick et al. 1996, McCormick and O'Dell 1996, McCormick et al. 1997, Cooper et al. 1999, Pan et al. 2000, McCormick et al. 1998). The type and sensitivity of response depends on the type and influence of the manipulated variable. Hydroperiod and nutrient alterations have different effects on different systems. Nutrient enhancement in an oligotrophic system would elicit a different suite of responses from that in a nearby degraded system. The quantity of supporting data and the spatial extent of applicability of those data is variable. Currently, much more data exist on effects of accelerated phosphorus loading on periphyton than effects of alterations in hydropattern and most studies have been confined to a few specific areas.

Few studies have evaluated the interaction of these two variables on periphyton. Although some useful generalizations may be obtained by integrating results from phosphorus-dosing experiments conducted in marshes of differing hydroperiod. For these reasons, we based the suitability indices on relationships that have the most empirical support and we explicitly state the certainty and range of applicability of resulting models. The formulation of these models has resulted in a list of research needs, included at the end of this chapter, with the expectation that the suitability indices will evolve over time with the generation of novel results.

Hydrologic Variables

The periphyton-based hydrologic suitability index was partitioned into three separate models because three structurally different communities occur across the Everglades hydroscape (Browder et al. 1994). Structural and functional responses to hydroperiod alterations vary depending on the hydroperiod range to which the mat has been historically exposed. Periphyton in short-hydroperiod marshes (flooded 0-8 months) is typically consolidated into either sediment-associated mats or "sweaters", the thick, spongy coatings on submerged stems of emergent macrophytes. Because they are associated with a limestone substrate and are regularly exposed to oxidation, these mats are typically highly calcareous. Persistent flooding in longer-hydroperiod marshes (flooded 8-30 months) encourages production of submerged macrophytes that become an important floating substrate for periphyton. Floating calcareous mats, often termed "metaphyton", predominate in these systems. Finally, the longer-hydroperiod marshes (flooded more than 30 months) of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR) contain a peat-forming plant community that supports a very different, acid-loving epiphytic periphyton assemblage.

The parameters used to measure suitability of a particular hydroperiod range differ according to the community type, but will be a designated subset of the following features: proportion of mat existing in the optimal growth form for the hydroperiod range, aerial cover of the mat, proportion of nonblue-green algae, proportion organic content and presence of preferred attachment substrate. The form of the final suitability function for each hydroperiod range is a composite of the responses of the selected parameters and the three models can be mathematically combined into a composite function that encompasses the entire gradient. All three models are solely a function of the period-of-simulation (31 years) average hydroperiod computed from South Florida Water Management Model version 3.5 (SFWMM) and Natural System Model version 4.5 (NSM) output. The SFWMM and NSM grid cells applicable to these periphyton communities for the periphyton suitability index are presented in **Figure 5-2**.

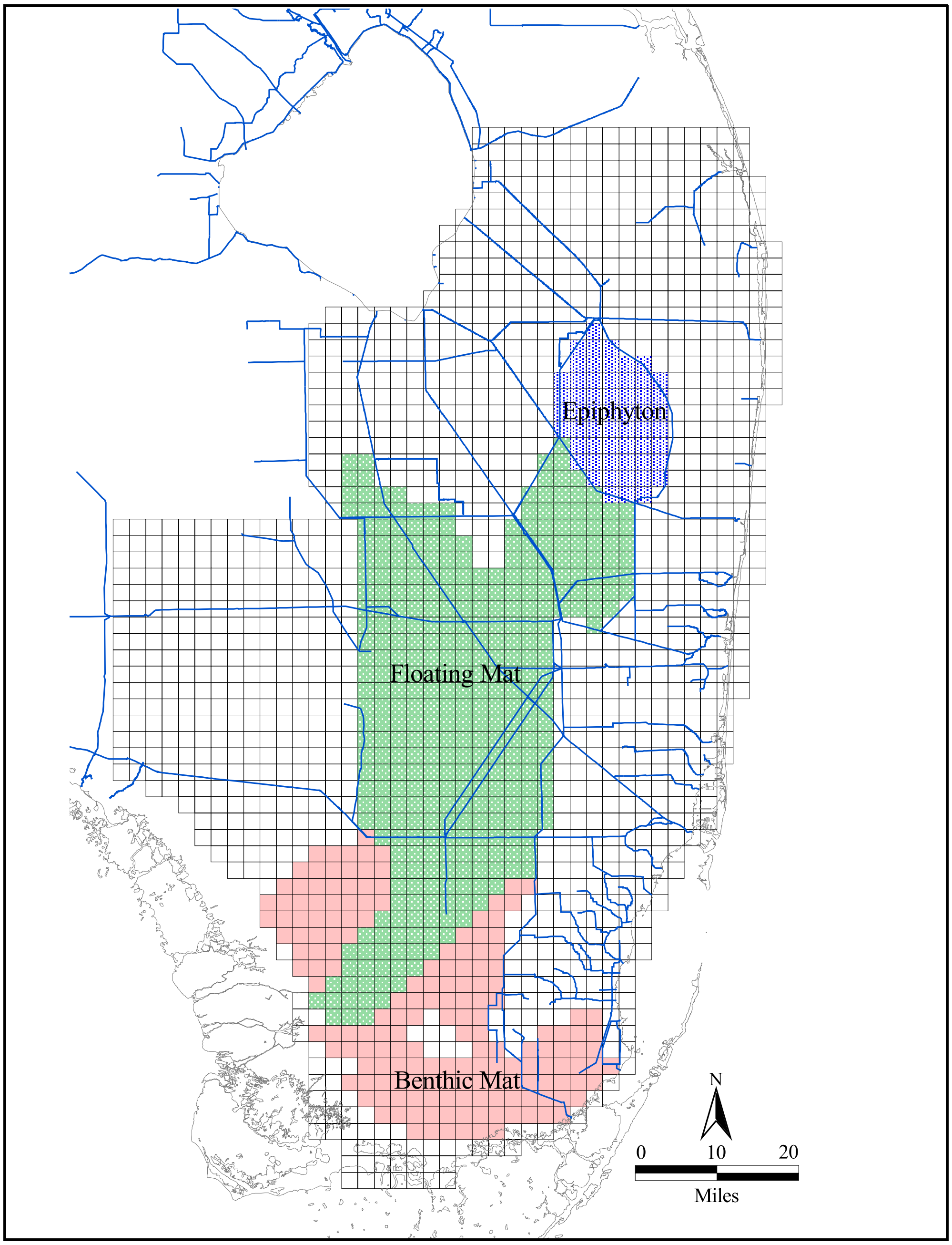


Figure 5-2. SFWMM grid cells applicable to the three different periphyton communities of the periphyton habitat suitability index.

Habitat Suitability Functions

Benthic Periphyton

Benthic, or sediment-associated, periphyton mats are an important component of shallow, short-hydroperiod Everglades marshes (Browder et al. 1994). Floating macrophytes are typically absent from these marshes so metaphytic periphyton mats are rare. However, often associated with benthic mats in these systems are thick growths of epiphytes, or sweaters, on the submerged stems of the emergent macrophytes (typically either *Eleocharis* spp. or *Cladium jamaicense*). For the purposes of our models, we combine benthic and sweater-forming mats into a single category. Benthic mat models should be applicable to areas with an average hydroperiod of less than 8 months, which includes eastern Shark River Slough, Taylor Slough (see **Figure 3-1**), northwestern Shark River Slough and portions of Water Conservation Area (WCA) 3A (to the north) and WCA 2A (central) (see **Figure 1-1** for location of all areas except Taylor Slough). Three features contribute to the suitability index for benthic mats: 1) percent benthic/sweater periphyton of total periphyton biomass, 2) percent organic content of mat, and 3) proportion of the community comprised of nonblue-green algae.

Percent Benthic Periphyton

Benthic periphyton mats are usually absent from marshes that are only flooded for a few days. However, because mats are dominated by species that are relatively resistant to desiccation, they regenerate fairly quickly after prolonged drying. Thin periphyton films appear on lime rock or marl substrate after days of reflooding while thick mats may take several years of repeated 1 to 2 month flooding episodes to form. Once formed, these mats form a fairly uniform cover across large areas and only disappear when 1) water depths increase above 2 feet when carbonate dynamics and light attenuation limit production and 2) hydroperiod exceeds the point that limits the production of metaphyton-supporting submerged plants (i.e., *Utricularia purpurea*, which becomes important when hydroperiods exceed 8 months).

Percent Organic Content of Mat

Because benthic mats proliferate in short-hydroperiod marshes, they are frequently exposed to oxidative removal of accumulated organics. They form on lime rock substrates and are calcitic, contributing to the marl soils that characterize these marshes. The percent organic material in benthic mats increases with increasing hydroperiod.

Percent Nonblue-green Algae in Mat

Most mat taxa are relatively resistant to periodic desiccation but some return more quickly than others after reflooding events. The mat-forming filamentous blue-green algae have been shown to be particularly drought-resistant. Although diatoms and green algae are generally not as resistant to drought, some species have been identified as “aerophilic” and capable of withstanding prolonged drought. Work in the Everglades to define these taxa is under way but data are not yet ready for incorporation into these models. Data from limited surveys and ongoing experimental work suggest that the best community-based index of hydroperiod for benthic mats will come from the ratio of filamentous blue-green algae to other elements in the mat. This ratio increases with the duration of drought (Browder et al. 1981, E. Gaiser, Florida International University, unpublished data, A. Gottlieb, Florida International University, unpublished data). Because this ratio shows strong promise in providing early indication of ecological effects of altered hydroperiod, it should be considered a major research need.

Benthic Periphyton Suitability Index

Based on these three features, a benthic periphyton suitability index (BPSI) as a function of the average hydroperiod over the period of simulation (t in months) is defined as follows (**Figure 5-3**):

$$\mathrm{BPSI} = 1 - \exp[-(t/2)^3] \text{ for } t \leq 4 \text{ months}$$

$$\mathrm{BPSI} = \exp[-(t/14)^7] \text{ for } t \geq 4 \text{ months}$$

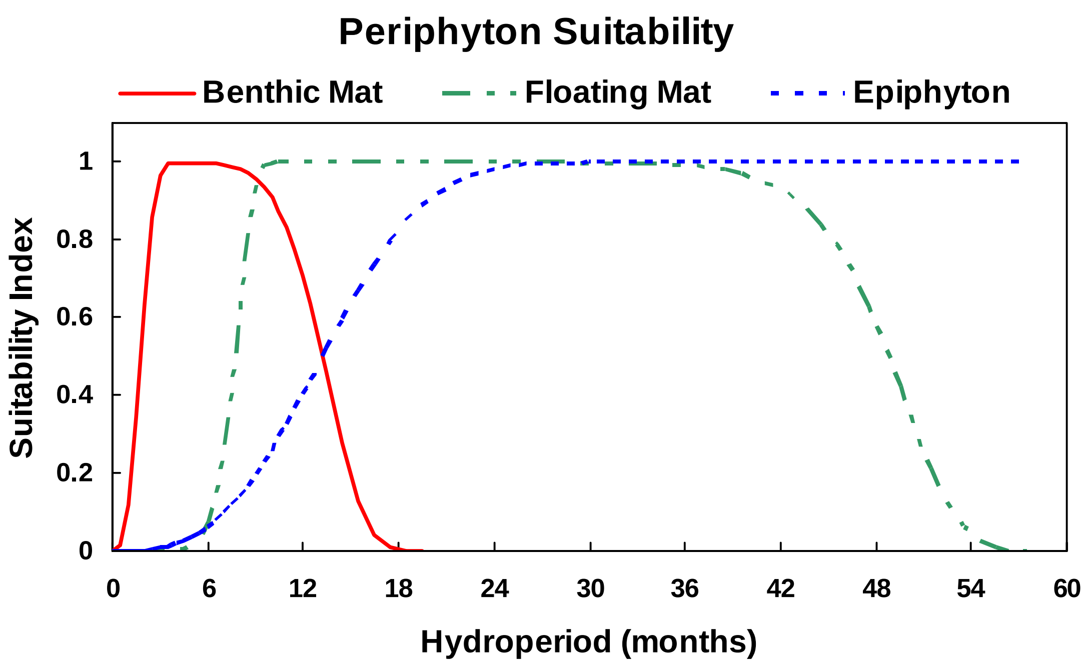


Figure 5-3. Periphyton suitability as a function of hydroperiod for benthic, floating and epiphytic mat communities.

Floating Periphyton

In deeper, longer-hydroperiod Everglades marshes, periphyton occurs either in benthic aggregations, sweaters on submerged stems of emergent macrophytes, or as floating metaphyton on submerged macrophytes. The latter is the predominant form of periphyton in central Shark River Slough and WCA 3A. The formation of floating mats appears dependent on the availability of floating substrate, most often the purple bladderwort, *U. purpurea*, which is poorly adapted to desiccation and, therefore, excluded from shorter-hydroperiod sites. Thick floating periphyton mats substantially reduce light penetration to sediments and, therefore, prohibit the coexistence of productive benthic periphyton mats. The upper hydroperiod limit for floating mats appears to be determined by carbonate dynamics. Floating mats do not occur in acidic wetlands with peat soils that have formed during episodes of prolonged flooding (i.e., LNWR). Floating mats are presently the predominant form of periphyton in ridge and slough wetlands with hydroperiods ranging from 8 to 30 months, which includes central Shark River Slough, and most of WCA 3A and WCA 2A. Three features contribute to the suitability index for floating mats: 1) percent aerial cover of floating mat, 2) percent organic matter content of mat, and 3) abundance of the preferred attachment substrate, *U. purpurea*.

Percent Aerial Cover of Floating Mat

Floating mats typically occur in patches associated with *U. purpurea* in *Eleocharis*, sparse *Cladium*, and *Nymphaea*-dominated marshes. Patchiness is on the order of several meters and appears correlated with the patchiness of the vegetation. Areas that are for various reasons devoid, but surrounded by, floating mats typically have benthic or sweater periphyton communities. This patchiness must be taken into account in evaluating periphyton cover. In addition, floating periphyton mats undergo a seasonal senescence, possibly related to the seasonality of *U. purpurea*. Therefore, we can define two models that relate floating periphyton mat cover to hydroperiod: one for the dry season and one for the wet season. These can be expressed as one function of hydroperiod, but mat cover varies.

Percent Organic Content of Mat

The organic content of floating periphyton mats is correlated with hydroperiod and water depth. Periphyton in shallow, short-hydroperiod wetlands typically have greater access to bicarbonate, which is removed by filamentous blue-green algae and precipitated into calcite crystals that maintain the structural integrity of the mat. In peat-based, longer-hydroperiod wetlands, the pH is typically lower and periphyton is predominantly comprised of highly organic, noncalcareous algae that do not form floating conglomerates. Data showing the relationship of periphyton organic content to hydroperiod helps us define the suitability index as a function of hydroperiod.

Abundance of U. purpurea

Floating periphyton mats are often associated with the submerged macrophyte *U. purpurea* that forms the backbone of the mat. While other species of bladderwort are common in shorter-hydroperiod marshes, *U. purpurea* is usually absent from marshes that are flooded for less than 4 months. Rather, it is an important component of the ridge and slough system, and shares a common distribution with *Nymphaea odorata* and other slough macrophytes. *U. purpurea* is abundant in acidic portions of the system (i.e., LNWR) as well, but in these areas it does not support a calcareous floating mat but rather is coated by a thick organic-rich epiphytic periphyton community.

Floating Periphyton Suitability Index

Based on these three features, a floating periphyton suitability index (FPSI) as a function of the average hydroperiod over the period of simulation (t in months) is defined as follows (**Figure 5-3**):

$$FPSI = 1 - \exp[-(t/8)^{9}] \text{ for } t \leq 10.5 \text{ months}$$

$$FPSI = \exp[-(t/50)^{15}] \text{ for } t \geq 10.5 \text{ months}$$

Epiphytic Periphyton

In peat-based wetlands with deeper water and longer hydroperiods, periphyton is abundant but does not form calcareous conglomerated mats (Gleason and Spackman 1974, Swift and Nicholas 1987). Rather, the periphyton is a flocculent algae and bacteria-rich matrix that grows attached to the submerged stems of aquatic plants. This is the predominant form of periphyton in LNWR. This type of epiphytic periphyton should not be confused with “sweaters”, which are calcareous aggregations that form in short-hydroperiod wetlands. Three features contribute to the suitability index for epiphytic periphyton: 1) percent organic matter content, 2) percent nonblue-green algae in the periphyton, and 3) abundance of submerged attachment surfaces.

Percent Organic Matter Content

The organic matter content of periphyton is highly correlated with hydroperiod, particularly at the upper end of the hydroperiod spectrum. Epiphytic periphyton aggregations, occurring in the longest hydroperiod marshes, are nearly 100 percent organic being incapable at the resident pH of precipitating calcite crystals. A decrease in hydroperiod in LNWR, however, may not induce the production of calcitic floating mats as would be predicted with the hydroperiod model alone. Because LNWR is situated on a silica-sand substrate rather than lime rock, the pH may remain low enough to prohibit the formation of a calcite-precipitating periphyton flora.

Percent Nonblue-green Algae

Recent studies across the Everglades system suggest that as hydroperiod and water depth increase, the abundance of filamentous blue-green algae that thrive in shallow, calcareous wetlands decreases. Communities in LNWR are dominated by an entirely different assemblage of acid-loving taxa, including an abundance of desmid algae and diatoms (Gleason and Spackman 1974, Swift and Nicholas 1987). This flora may have been important in large areas of the northern Everglades before modern canal construction increased the pH and decreased the water levels in adjacent marshes (Slate and Stevenson 2000). It would be expected to reappear in these areas if hydroperiod was lengthened, but the return may happen slowly, only after peat accumulations deepen and pH is reduced below approximately 6 to 7. As for benthic mats, a model that directly explains the relationship between nonblue-green algae and hydroperiod and/or water depth should be a major research aim because of the potential applicability in providing a reliable index of changing water availability.

Abundance of Attachment Substrate

In acidic wetlands with an abundance of submerged macrophytes, epiphytic periphyton predominates. It may be excluded when vegetation becomes too dense to permit light penetration to stems but also when water depth exceeds the limits that support the growth of macrophytes. At this upper end, epiphytic algal assemblages are replaced by phytoplankton. This depends on limits to the depth of growth of macrophytes that exceeds depths currently represented in the Everglades system.

Ephiphytic Periphyton Suitability Index

Based on these three features, an epiphytic periphyton suitability index (EPSI) as a function of the average hydroperiod over the period of simulation (t in months) is defined as follows (**Figure 5-3**):

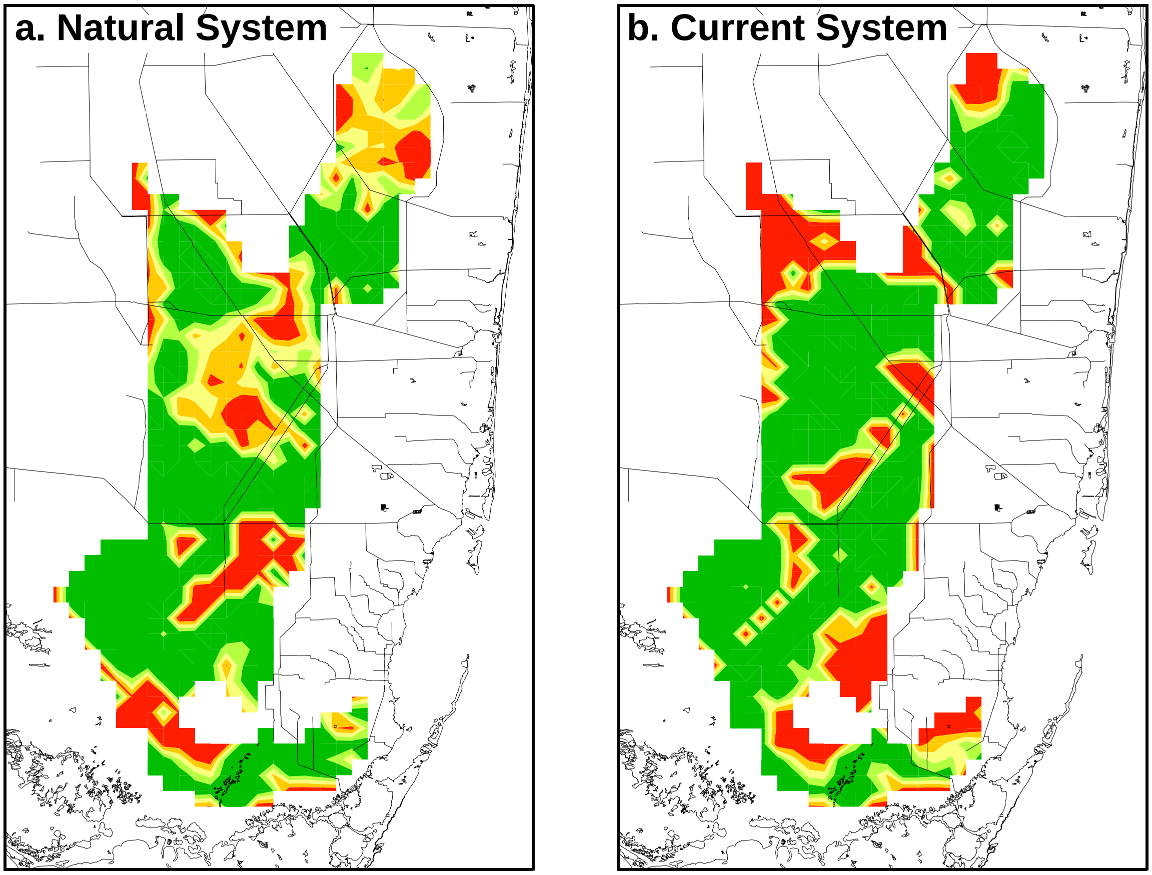
$$EPSI = 1 - \exp[-(t/15)^3]$$

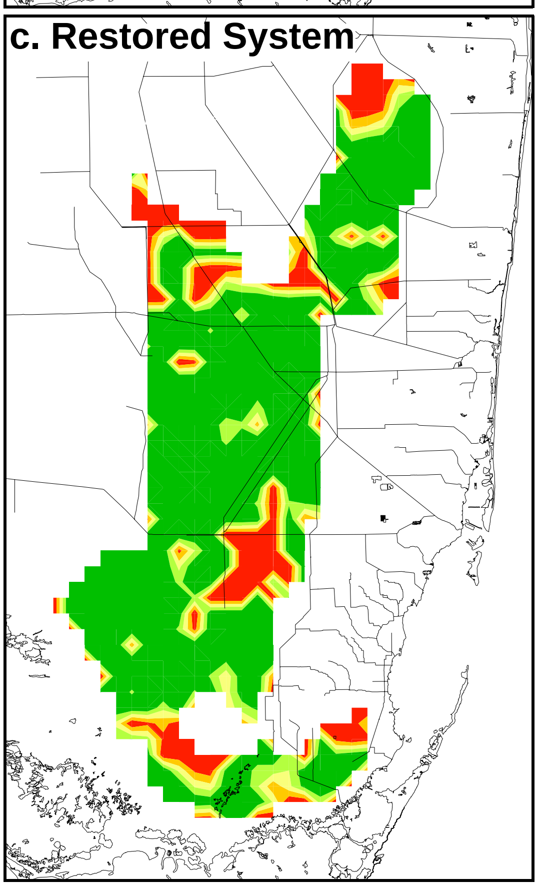
Results

Initial results indicating the performance of the periphyton suitability indices are shown for the natural, current, and restored systems in **Figure 5-4**. Periphyton suitability is a direct function of the average hydroperiod for the period of record (31 years from 1965-1995) as indicated in **Figure 5-5**.

The epiphyton habitat suitability index was applied to LNWR (**Figure 5-2**). Simulated natural system hydroperiods were typically 8 to 12 months with some areas experiencing hydroperiods longer than a year (**Figure 5-5a**). Because the long-hydroperiod epiphyton suitability index was applied to this area, suitability was low (generally less than 0.4, **Figure 5-4a**). Model results indicated that for the current system (**Figure 5-5b**) hydroperiods in LNWR were longer than they were in the natural system due to impoundment that favors the production of epiphytic periphyton. Epiphyton suitability for the current system declined from values greater than 0.8 in the southern two-thirds of LNWR to values of less than 0.2 in the north of LNWR (**Figure 5-4b**). This was due to a hydroperiod gradient from inundation of longer than 3 years in the south of LNWR to less than 4 months of inundation in the extreme north of LNWR (**Figure 5-5b**). Hydroperiod and epiphyton suitability in the restored system were similar to that of the current system (**Figures 5-4c** and **5-5c**).

In the water conservation areas and Shark River Slough, the medium-hydroperiod floating mat periphyton suitability index was applied (**Figure 5-2**). Hydroperiods in the natural system were longer than 8 months in WCA 2, from 4 to 12 months for most of WCA 3, and longer than a year for the southernmost parts of WCA 3A and WCA 3B (**Figure 5-5a**). Floating periphyton suitability was greater than 0.8 in WCA 2 and in





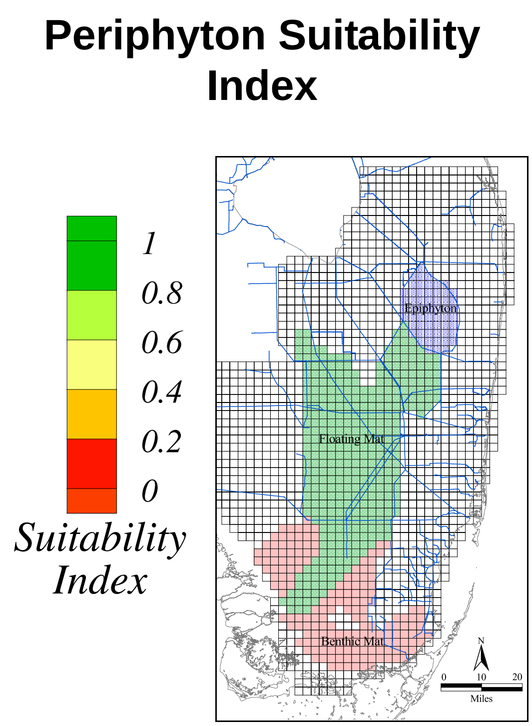


Figure 5-4. Mean annual periphyton suitability index for the a. natural system, b. current system, and c. restored system.

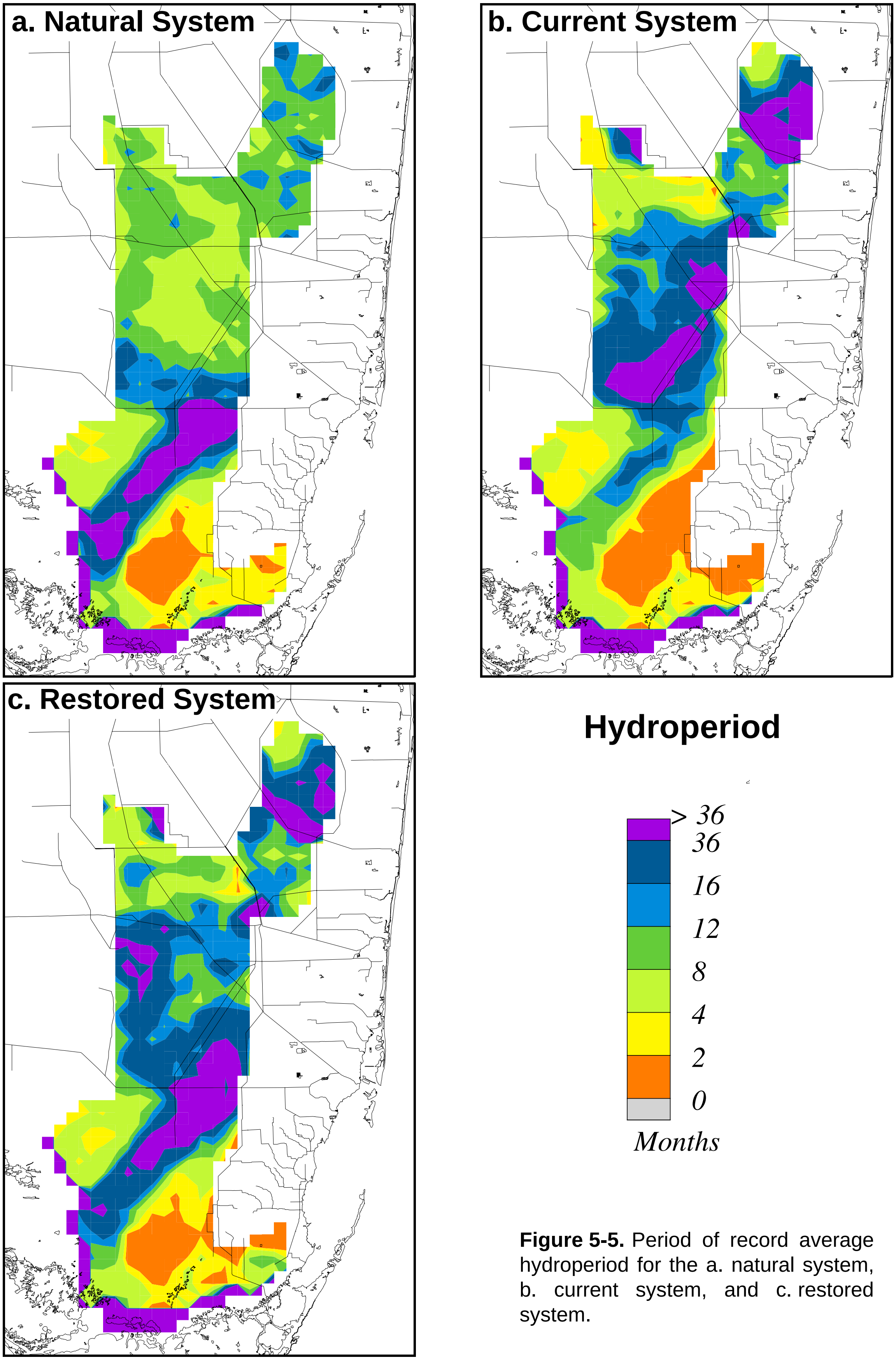


Figure 5-5. Period of record average hydroperiod for the a. natural system, b. current system, and c. restored system.

northwestern and southern WCA 3 (**Figure 5-4a**). In central WCA 3, where hydroperiods were shorter than 8 months (**Figure 5-5a**), suitability for floating periphyton declined (FPSI value from 0.6 to less than 0.2, **Figure 5-4a**). In Shark River Slough, hydroperiods, typically longer than 3 years, were unsuitable for the production of floating periphyton because they were too long (FPSI values less than 0.2, **Figure 5-4a**). However, hydroperiods of this length would tend to favor the production of epiphytic periphyton. In the current system, hydroperiods of 8 to 36 months (**Figure 5-5b**) for most of the WCA 2 and WCA 3 and Shark River Slough were suitable for the production of floating periphyton (FPSI values greater than 0.8, **Figure 5-4b**). Shorter hydroperiods (less than 8 months) in northwestern WCA 3A and longer hydroperiods (more than 2 years) in the deeper parts of WCA 3A along the L67 canal (**Figure 5-5b**) were less favorable for floating periphyton production (FPSI values less than 0.2, **Figure 5-4b**).

The benthic periphyton suitability index (BPSI) was applied to the marl prairie areas of Everglades National Park (**Figure 5-2**). Hydroperiods of 2 to 12 months in most of the marl area for the natural system (**Figure 5-5a**) resulted in high BPSI values (more than 0.8, **Figure 5-4a**). Hydroperiods and resulting benthic periphyton suitability were similar for the current and restored systems except in the extreme eastern marl area where hydroperiods of less than 2 months in the current system resulted in low PBSI values (less than 0.2, **Figure 5-4b**).

Examination of results of periphyton suitability indices as discussed in the preceding three paragraphs illustrates the usefulness of habitat suitability indices and the care that needs to be taken in applying them to specific areas. Areas with low suitability values highlight areas needing further examination of the underlying cause for the poor suitability or reassessment of appropriateness of the suitability index applied to these areas. For example, floating periphyton suitability indices that were low (less than 0.2) occurred in the natural system simulation both in drier areas (hydroperiods too short) and in wetter areas (hydroperiods too long). Application of the epiphytic periphyton suitability index to LNWR assumed a desired restoration condition supportive of long-hydroperiod epiphyton in this area. This is different from what may have been in LNWR under predrainage conditions, best simulated with the Natural System Model (NSM), which indicated shorter hydroperiods and an environment possibly better suited to the production of floating mat periphyton. Had the floating mat periphyton index been applied to LNWR, periphyton suitability values in LNWR would likely have been better in the simulated natural system than in the current or restored systems, rather than the reverse. Application of the suitability indices and careful examination of their results help focus future research efforts to reexamine restoration targets or highlight deliberate decisions to have restoration targets with hydroperiods and resulting periphyton suitability indices different from those in the natural system.

Future Research

The exercise of defining three distinct structural types of periphyton and developing and applying hydroperiod-related habitat suitability indices was a productive one. Application of the models to the natural, current, and restored systems led to the following conclusions. Hydroperiod and water depths across the Everglades have changed to such an extent that it is inappropriate to use current hydroperiod and water depths to determine the type of periphyton model to be applied to each area or to designate boundaries between areas. Furthermore, additional research is needed to develop an accurate quantitative relationship of each structural type of periphyton to hydroperiod and other conditions. Experiments should be conducted to better document species responses to changing hydroperiod and relationships of periphyton dynamics to that of the vegetation. Taxonomic survey data should be analyzed with the goal of determining algal species hydroperiod optima and tolerances.

Periphyton production, species composition, and physical structure have been shown to vary greatly along existing and experimental phosphorus gradients (Swift and Nicholas 1987, Grimshaw et al 1993, Raschke 1993, Vzmazal and Richardson 1995, McCormick et al. 1996, McCormick and O'Dell 1996, McCormick et al. 1997, 1998, Cooper et al. 1999, Pan et al. 2000, Gaiser et al. 2001a, 2001b, 2004). Alteration in hydroperiod may change the phosphorus load. Change in water depth may affect phosphorus availability and uptake. Few experiments have examined the interaction of hydroperiod, depth, and phosphorus on ecosystem structure and function. Experiments should be conducted to determine effects of phosphorus loading on the different types of periphyton communities that occur across the system. Researchers should take advantage of “natural” experiments provided by long-term monitoring along existing phosphorus gradients where hydroperiods are being altered (or hydroperiod gradients where phosphorus is being altered).

It is also important to understand periphyton responses to the interplay of other water chemistry parameters (silica, dissolved oxygen, bicarbonate, dissolved carbon dioxide, and chloride) with hydrology because these parameters also vary across the system and may be changed with altered water delivery and hydropatterns. Finally, water flow velocity, which may also change, may have an effect on periphyton structure and composition as it does in other systems, and this effect has not been studied in the Everglades.

The Everglades is a mosaic in hydrologic, biotic, and biogeochemical terms, and its mosaic nature will have to be taken into account when designing and applying periphyton habitat suitability indices. The greatest benefit of this exercise is to elucidate the necessary focus of new periphyton research and demonstrate its potential usefulness.

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